

More Examples

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Program construction in C++ for Scientific Computing



Outline

① A Complete Example

② Another Example

③ Summary

The Problem

Write a program with the following properties:

- The user provides the dimension n of two vectors.
- The program allocates two vectors of the required size and fills them with meaningful data.
- The program computes the scalar product of the two vectors and prints the result.

The Algorithm

- We choose the vectors to be

$$x_i = i$$

$$y_i = \sin x_i$$

for $i = 0, \dots, n-1$.

- The scalar product is given by

$$s = \sum_{i=0}^{n-1} x_i y_i$$

The Scalar Product Function

```
double scprod(int n, double x[], double y[]) {  
    double sum = 0;  
    for (int i=0 ; i < n ; i++) sum += x[i]*y[i];  
    return sum;  
}
```

The length n of the vectors must be given as a parameter. There are no means to find it out inside the routine.

The Main Program

```
#include <iostream>
#include <cmath>
using namespace std;
double scprod(int n, double x[], double y[]);
int main() {
    double *x, *y;
    cout << "Give vector size ";
    int n; cin >> n;
    x = new double[n];
    y = new double[n];
    for( int i = 0 ; i < n ; i++ ) {
        x[i] = i;
        y[i] = sin(x[i]);
    }
    cout << "Scalar product is " << scprod( n, x, y ) << endl;
    delete[] x;
    delete[] y;
}
```

Good Programming Style: Data Abstraction And Encapsulation

- The main program must know how the scalar product function is called. However, it is not necessary to know how it is implemented.
- Consequence: Subdivide the function into a file containing the declaration (the so-called header file) and its definition.

Data Abstraction

Data abstraction is a programming (and design) technique that relies on the separation of *interface* and *implementation*.

Encapsulation

Encapsulation enforces the separation of interface and implementation.

While it is a good programming style in C, it is an essential feature of C++!

Interface: The Header File scprod.hpp

```
#ifndef SCPROD_HPP
#define SCPROD_HPP

double scprod(int n, double x[], double y[]);

#endif
```

The use of the macro `SCPROD_HPP` prevents a double inclusion (which may lead to a syntax error).

The Implementation `scprod.cpp`

```
#include "scprod.hpp"

double scprod(int n, double x[], double y[]) {
    double sum = 0;
    for( int i=0 ; i < n ; i++ ) sum += x[i]*y[i];
    return sum;
}
```

The header is included in order to ensure that the declaration and the definition of `scprod` coincide.

The Main Program

```
#include <iostream>
#include <cmath>
#include "scprod.hpp"
using namespace std;
int main() {
    double *x, *y;
    cout << "Give vector size ";
    int n; cin >> n;
    x = new double[n];
    y = new double[n];
    for( int i = 0 ; i < n ; i++ ) {
        x[i] = i;
        y[i] = sin(x[i]);
    }
    cout << "Scalar product is " << scprod( n, x, y ) << endl;
    delete[] y;
    delete[] x;
}
```

The Problem

Write a library routine for the secant method and test it with some examples.

The Algorithm

The secant method works as follows for solving the equation $f(x) = 0$:

$$x_{i+1} = x_i - \frac{f(x_i) - f(x_{i-1})}{x_i - x_{i-1}} f(x_i)$$

with given x_0, x_1 .

The Header secant.hpp

```
#ifndef SECANT_HPP
#define SECANT_HPP

typedef double (*FunctionPointer)(double);

double secant(double a, double b, FunctionPointer f);

#endif
```

The Implementation secant.cpp

```
#include <iostream>
#include <cstdlib>
#include <cmath>
#include "secant.hpp"

double secant(double a, double b, FunctionPointer f) {
    double tol = 1e-15;
    double x,y,fa,fb;
    int niter = 0;
    fa = f(a); fb = f(b);
    while(fabs(b-a)>tol && fa!=fb) {
        niter = niter+1;
        if(niter > 100) {
            std::cerr << "No convergence! Exiting..." << std::endl;
            exit(1);
        }
        x = a - (b-a)*fa/(fb-fa);
        y = f(x);
        b = a ; a = x;
        fb = fa; fa = y;
    }
    return a;
}
```

The Main Program

```

#include <iostream>
#include <iomanip>
#include <cmath>
#include "secant.hpp"
using namespace std;
double sinpluscos(double x) { return sin(x)+cos(x); }
int main(void) {
    double y1,y2,y3,y4;
    y1 = secant(-1.0,1.0,&sin);
    y2 = secant(3,4,&sin);
    y3 = secant(1,2,&cos);
    y4 = secant(-1,-2,&sinpluscos);
    cout << "f          x          f(x)" << endl;
    cout << scientific;
    cout << "sin(x)          " << y1 << " " << sin(y1) << endl;
    cout << "sin(x)          " << y2 << " " << sin(y2) << endl;
    cout << "cos(x)          " << y3 << " " << cos(y3) << endl;
    cout << "sin(x)+cos(x) " << y4 << " " << sinpluscos(y4) << endl;
    return 0;
}

```

Program Output

f	x	f(x)
sin(x)	0.000000e+00	0.000000e+00
sin(x)	3.141593e+00	1.224647e-16
cos(x)	1.570796e+00	6.123234e-17
sin(x)+cos(x)	-7.853982e-01	-1.110223e-16

Summary

- We developed two numerical programs.
- Data abstraction and encapsulation
- What will come next:
 - The basics of object oriented programming: C++ classes